THE YIELD CURVE AS A PREDICTOR OF GROWTH AND RECESSION IN AUSTRALIA

by
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Abstract

This paper estimates the slope of the yield curve using quarterly data on real GDP and the nominal spread proxied by the difference in returns from the 10 year bond rate and the 90 day bill rate. The time-series analysis after proper unit root tests using stationary variables revealed that the yield curve gives the best forecasts on real activity over a forecast horizon of one year (4 quarters) ahead. Non-nested tests of rival models of alternative financial indicators demonstrated that the yield curve outperforms other financial indicators as a robust predictor of future real activity.

The Probit model forecasts of recessions indicated that the inverted slope of the yield curve for 4-quarter horizon gave the best recession prediction for Australia. The probit model predictions also gave probability estimates for the occurrence of recessions for different nominal spreads or slopes of the yield curve. The probit model predictions of recessions improved dramatically when a dynamic lag structure was incorporated.

Empirical evidence demonstrates that the yield curve outperforms other financial indicators as a predictor of recessions in Australia. It is a simple and operational tool that can be validated using up-to-date data.

Keywords

Yield curve. Business cycle turning points. Expectations theory. Inverted slope of the yield curve. Probit models. Dynamic probit models Predictions of recessions. Australia.

JEL Classification Codes: C22, C25, E43

1. Introduction

Financial indicators have been widely acknowledged as good predictors of business cycle turning points since the pioneering NBER studies conducted over half a century ago (Mitchell and Burns, 1938). Amongst financial indicators the slope of the yield curve appears to outperform its rivals as a simple and reliable predictor of economic activity over short-term forecast horizons. The yield curve posits a relationship between the spread and the difference between long-term and short-term interest rates on securities that are comparable in every respect except the term to maturity. In USA it has been observed that the slope of the yield curve inverts (becomes negative) or flattens before the onset of a recession (Stock and Watson, 1988; Estrella and

Hardouvelis, 1991). Such inversions have also been observed for many other OECD countries (Bernard and Gerlach, 1996; Bosner-Neal and Morley, 1977; Kozicki, 1977). Some analysts claim that the yield curve is a near perfect tool for predicting economic activity (Clark, 1966) and as single indicator it is credited with doing a better forecasting job of recessions than most complex macroeconometric models (Economist, 1998). There is both theoretical and empirical evidence supporting the yield curve ability to forecast future turning points in the business cycle. It is a parsimonious, simple construct that can be readily estimated using up-to-date information. Yield curve forecasts can supplement both judgmental and more sophisticated forecasts based on multi-equation econometric models such as the Treasury Model (TRYM) and forecasts made by leading indicators of the Institute of Social and Applied Economic Research (IASER).

This paper aims to add further insights to the Australian research on the relationship between the yield curve and real economic activity (Lowe, 1992; Alles, 1995; Fisher and Flemingham, 1997) by updating yield curve prediction of recessions in Australia using probit techniques applied to the US context recently (Estrella and Mishkin, 1998). The paper also uses a parsimonious time-series database to forecast real economic activity using proxies that will facilitate the international comparability of forecasts. In this paper non-nested tests have also been applied to shed light on the issue of whether the yield curve outperforms economic activity and recession predictions by other rival financial indicators over forecast horizons of one year (four quarters) into the future.

The paper is organised as follows: Section 2 reviews the macro-theoretic foundations that rationalise the use of the slope of the yield to predict variations in macroeconomic activity and more specifically recessions. Section 3 reports the yield curve fits over different forecasting horizons in order to identify the best fitting yield curve for Australian quarterly time series data for the sample period 1993Q2- 1997Q3. Section 4 presents the theory of probit modelling a binary response or recession dummy dependent variable using the nominal spread as the explanatory variable. The probability estimates for recessions as spreads vary are also reported here. Section 5 presents the probit probabilities for predicting a recession when the model is enhanced by incorporating a dynamic lag structure. Section 6 concludes the paper.

2. Macro-theoretic foundations of the yield curve

The yield curve estimates a relationship between the growth rate of real GDP (Δy_{t+j}) j-quarters ahead and the spread term or the difference between the interest rate for long-term and short-term securities (s_t), providing a yield curve equation:

$$\Delta y_{t+j} = \alpha + \beta s_t + \varepsilon_t .$$

The slope of the yield curve, the coefficient (β) if positive, predicts a recovery and if negative or inverted predicts a recession at a future forecast horizon (t+j) quarters.

Several macroeconomic theories provide support for the stylised relationship between real economic activity and the nominal spread between long and short-term interest rates on debt securities. Amongst these theories are: the expectations, liquidity preference, preferred habitat, policy-stance, and the consumption-smoothing hypotheses.

The expectations hypothesis postulates that the long-term interest rate is a weighted average of current and expected future short-term interest rates (Fisher, 1986; Lutz, 1940). Thus, if the current short-rate were less than the long-rate, the future short-rate would exceed the long-rate. If the pure expectations hypothesis holds under the joint postulates of rationality and risk neutrality then $\delta_0 = 0$ and $\delta_1 = 1$ in the equation:

$$s_{t+j} = \delta_0 + \delta_1 s_t + \varepsilon_t$$

where s_t defines the spread. Empirical tests for Australia lend support for the expectation hypothesis as the yield spread Granger causes future changes in the short-rate (Karfakis and Machos, 1995). However, many international studies reject the pure expectation hypothesis because of the violation of rationality and risk neutrality (Mankiw, 1986; Taylor, 1992).

The liquidity preference hypothesis modifies the expectations hypothesis by incorporating a risk premium to compensate risk-averse investors for investing in long-term bonds (Hicks, 1939). The risk premium, by making the long-term rate greater than the short-term rate, imparts a positive bias to the slope of the yield curve. According to the market segmentation and preferred habitat hypothesis the slope of the yield curve would reflect the preference of institutional investors for either long or short-term interest rates (Modigliani and Sutch, 1966). The policy-stance hypothesis postulates that the slope of the yield curve reflects the tightness of monetary policy. For example, if the Reserve Bank engages in tight monetary policy this would cause the short-term rate to rise, while the long-term rate responds sluggishly after a lag due to sticky prices. Thus the spread is narrowed and the yield curve is flattened reflecting the tight stance of monetary policy. The Keynesian IS-LM model provides a graphic illustration of this policy stance hypothesis as tightening of monetary policy shifts the LM curve to the left increasing the short-rate, thus reducing the spread and decreasing real output. A much more rigorous neoclassical explanation of the yield curve is proffered by the consumption-smoothing hypothesis underpinning the Consumption Capital Asset Pricing Model (CCAPM) (Campbell, 1988). Here the changes in the slope of the yield curve are attributed to intertemporal consumption decisions of forward-looking consumers. If a recession looms over the forecast horizon, forward-looking consumers will hedge against the expected bad times by purchasing long-term bonds causing their price to rise and long-term interest rates to fall. Consumers would finance the purchase of long-term bonds by the sale of short-term assets causing their price to fall and short-term interest rates to rise. Thus, the spread will decrease and the slope of the yield curve would either flatten or invert (become negative) presaging the onset of a recession. The effects of a negative productivity shock or technological regression under the Real Business Cycle (RBC) theory (Kydland and Prescott, 1988) provides a similar explanation for the flattening of the yield curve. Here the negative productivity shock will lead to the intertemporal substitution of current for future consumption causing the spread to become negative and the slope of the yield curve to invert. More complex stochastic general equilibrium modelling of the yield curve or the term structure using expectations theory as a foundation has also been undertaken allowing for a time varying risk premium (Cox et al., 1985). A comprehensive survey of the link between the term structure and the slope of the yield curve and economic activity is found in Van Horne (1994).

3. The yield curve as a real GDP growth predictor

The Australian yield curve has been fitted for quarterly time-series data for the sample period 1972Q3-1997Q3 (DXEcondata, 1997). The annualised growth rate of real GDP (expenditure measure) has been regressed on the nominal spread. The nominal spread has been quantified as the difference between the long-term and short-term interest rates, which are proxied by the 10 year Treasury bond rate and 90 day bank bill rate respectively. During the study period six episodes of recessions or slowdowns in real GDP were observed (See Table 1). The plots of real GDP and the slope of the yield curve exhibit a pattern, which is consistent with the deduction that inversions of the slope of the yield curve precede recessions. The slump in real GDP clearly lags the negative or inverted slopes of the yield curve (Fig. 1). When the yield curve is lagged 4-quarters the correspondence between the inverted slope of the yield curve and recessions (or a fall in real GDP) appear clearly (Fig. 2) lending support to the hypothesis that nominal yield curve acts as a good predictor of recessions or downturns in real activity.

Table 1. Episodes of recession or slowdown of real growth in Australia (1972Q2-1997Q3)

Episode	1	2	3	4	5	6
Quarters	77Q3-77Q4	77Q3-77Q4	82Q3-83Q2	86Q2-86Q3	90Q3-90Q4	91Q1-91Q3

Notes: A recession was defined as 2 or more consecutive quarters of negative growth.
A slow down was defined as 2 more consecutive quarter of <1% growth.

Further details on relations between the growth of real GDP and spread at a forecast horizon 4 quarters ahead and on a contemporary basis are reported in Table 2. It is noteworthy that the nominal spread exceeded –10.15 during the oil-shock recession and hovered around –2.64 to –2.83 during the "banana republic" recession episode.

Table 2. Growth slow downs and yield spreads for Australia
(1972Q2-1997Q3)

Qtr	74Q1	77Q3	77Q4	82Q3	82Q4	83Q1	83Q2	86Q2	86Q3	90Q3	90Q4	91Q1	91Q2	91Q3
y_{t+4}	0.22	0.58	-0.92	-1.58	-1.86	-2.28	-2.28	0.72	0.91	-0.13	-0.16	0.39	-1.33	0.75
s_{t+4}	-10.15	-0.36	-0.10	-0.10	1.29	0.89	-0.17	-2.64	-2.83	-0.58	0.12	-0.23	0.26	0.79
s_t	0.15	-0.10	0.94	-0.85	-0.03	-3.40	-2.78	-2.19	-2.41	-4.79	-4.92	-2.93	-1.50	-0.58

Explanatory notes:

dy_{t+4} = growth forecast 4-qtrs ahead
s_{t-4} = spread 4-qtrs ahead
s_t = contemporary spread term

In fitting a yield curve to time-series data it is imperative that we check for nonstationarity in the time-series by applying unit root tests. The ADF (Augmented Dickey Fuller) test was used to check for the order of integration (I) of the time-series used in this study. The optimal lag length (k) for making the residuals' white noise in the ADF test was determined on the basis of the minimum Schwarz Bayesian criterion (SBC). Once the order of integration of the series was determined it was appropriately differenced to obtain stationary or I(0) series, thereby reducing the dangers of spurious regression inferences. The ADF unit root tests for the time-series constituting the yield curve are reported in Table 3 below.

Table 3 ADF unit root tests and data sources
(1972Q3-1997Q3)

Variable	cal	tab	Lag (k)	Min SC	N	Order I
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5\	Col. 6	Col. 7
y_t	-1.61	-3.13	0	13.81	100	I(1)
S_t=D90	-1.85	-3.13	6	1.29	94	I(1)
L_t=B10	-1.82	-3.13	3	-0.74	97	I(1)

Explanatory notes:

ADF unit root test: $$\Delta y_t = \gamma_0 + \gamma_1 y_{t-1} + \gamma_2 T_t + \sum_{i=1}^{k} \beta_1 y_{i-1} + \varepsilon_t$$

With drift (γ_0) and trend term (γ_2)

Lower case letters refer to variables in logs.

y_t: real GDP (expenditure) 1989/90 prices.

S_t: short-term interest rate proxied by D90 or 90 day bank accepted bill rate.

L_t: long-term interest rate proxied by B10 or 10 year Treasury bond rate.

Col. 2 τ_{cal}: calculated value of ADF test-statistic, drift plus trend case.

Col. 3 τ_{tab}: tabulated MacKinnon critical value for ADF statistic.

Col. 4 lags (k) in the ADF test to render residuals white noise.

Col. 5 minimum value of Schwarz Criterion (SC) used to select optimal k.

Col. 6 n = sample size

Col. 7 order of integration of the variable.

Source: DX database for all quarterly time-series data used in the study.

The overlapping forecast horizons resulting in heteroscedastic errors that jeopardise the OLS regression estimates of the yield curve for forecast horizons ranging from j=1 to 12 have been rectified using the Newey-West correction, with Bartlett weights and a truncation lag=30 (Newey and West, 1987). The equation for the best fit yield curve for Australia has been reported in Table 4 with forecasts at horizons j=1, 2. 3, 4, 6, 8 and 12. The results of the yield curve forecasts revealed that the spread term loses its potency as a predictor of real growth as the forecast horizon extends beyond 4 quarters in to the future.

Table 4 Growth forecasts based on spread or slope of the yield curve (Newey-West corrected with Bartlett weights) (1975Q3- 1997Q3)

J	1	2	3	4	5	6	8	12
K	2.98	2.98	2.99	3.00	3.02	3.04	3.03	3.00
$\|t\|$	(20.00)	(19.22)	(18.98)	(19.42)	(21.77)	(22.24)	(12.74)	(20.38)
s_{t-j}	0.16	0.23	0.27	0.28	0.22	0.23	0.15	0.02
$\|t\|$	(3.18)	(2.94)	(3.15)	(2.98)	(1.51)	(1.68)	(1.50)	(0.28)
R^2	0.02	0.04	0.06	0.07	0.05	0.06	0.02	0.01
DW	0.74	0.76	0.79	0.80	0.77	0.75	0.72	0.73

Financial deregulation which involved the sale of government securities by tender rather than by tap and the floating of the AUD could have brought about a regime shift causing a structural break in the yield curve variables (Karfakis and Moschos, 1995:94). The parameter constancy and the forecast stability tests revealed that best fit yield curve for real GDP growth for forecast horizons 4-quarters ahead were unaffected by a structural break, thus confirming the Chow test finding that financial deregulation did not cause a structural break in the Australian yield curve (Alles, 1995:76).

The best fitting yield curve, after the Newey-West correction, for predicting real growth is:

$$\underset{|t|}{\Delta y_{t+4}} = \underset{(19.42)}{3.00^{**}} + \underset{(2.98)}{0.28 s_t^{**}}$$

Diagnostics

Parameter constancy 83Q4-97Q3:
Forecast Chi^2 (2,56) = 35.76
Chow F(56,39) = 0.51
Arch 4F(4,31) = 1.43
Chi^2 (2,36) =1.03
Reset (1,36) = -0.51
** Significant at 1% level.

The best fitting yield curve for Australia predicts that an increase in the nominal spread by 1% (100 basis points) increases real GDP growth by 3.28% per year or after 4-quarters. Non-nested tests were applied to determine whether the yield curve model encompassed or explained the variance in the rival model in an adequate manner. The preferred model (M_1) was tested against an array of rival financial indicator models as predictors of real GDP. The rival models were based on the stock market or the all ordinaries index (o_t); the monetary base (m_t) and the leading indicator (i_t). The J-test (Davidson and MacKinnon, 1981) can explain the logic underpinning the non-nested test procedures which are used to determine whether the yield curve model is superior to rival financial indicators in predicting real economic activity 4-quarters ahead. The null hypothesis specifies that the yield curve model (M_1) predicts real GDP growth better than the rival model represented by alternative financial indicators modelled by (M_2), the stock market indicator (M_2), the monetary base (M_3) or the leading indicator (M_4).

The J-test that the yield curve model (M_1) is a better predictor of future real growth than rival financial indicator models (M_i), where i=1,2,3,4 is implemented in a sequential manner as follows: First, the fitted values from a rival model (f_t) are added on to the yield curve model (M_1) thus: $\Delta y_t = \alpha + \beta s_t + \theta f_t + \varepsilon_t$. Second, if the t-statistic of the fitted coefficient (f_t) in the augmented model M_1 is non-significant, then we can conclude that the model (M_1) is a superior predictor of real GDP than the rival model: M_i. The J-test is basically a t-test on the fitted value from a rival model. If the t-statistic is non-significant then it supports the inference that the preferred model is superior to the rival model or M_1 is superior to any M_i. This implies that the model (M_1) encompasses or explains, in terms of variance, the behaviour of the rival model (M_i). The J-test is an asymptotic test and lacks good small sample properties. In the small sample case alternative tests such as the Cox N, the NT and the Wald-test should be used instead of the large sample J-test and JA-tests. The JA-test is asymptotically equivalent to the J-test and the encompassing test is a traditional F-test and has been used to determine whether the regressors of the rival model are jointly significant when incorporated in the preferred model in Table 5 and further details on these tests are found in Microfit 4.0 (Pesaran and Pesaran, 1997:355-357).

The t-statistic for the fitted values of the rival models ($M_{i\ i=2,3,4}$) when regressed in the enhanced yield curve model M_1) are non-significant implying that the yield curve model is superior to the rival financial indicator models according to the J-test (See Table 5). The other non-nested tests also give non-significant test statistic confirming the J-test result. This is further reinforced by the AIC and SBC model selection criteria. These criteria indicate that the yield curve model (M_1) is preferred over the rival financial indicator models ($M_{i\ i=2,3,4}$).

Residual based model selection criteria such as the Akaike Information Criterion (AIC) (Akaike, 1974) and the Schwarz Bayesian Criterion (SBC) (Schwarz, 1978) are used to determine whether the true model is superior to the rival model when the non-nested tests such as the J-test gives ambiguous results. The SBC test is regarded as more robust than the AIC test on the grounds of consistency or the availability of maximum information, with probability tending to unity as the sample size tends to infinity. The SBC criterion for choice between model M_1 against the rival model M_i can be computed using the following specification: $SBC(M_1 : M_i) = LL_1 - LL_2 - (k_1 - k_2)\log(n)/2$, where LL are the loglikelihood functions of the respective models. Model M_1 is preferred to model M_i if SBC ($M_1 : M_i$)> 0, otherwise M_i is preferred to M_1. The AIC model selection criterion has a similar explanation as the one given for the SBC criterion. The results for the model selection criteria are reported in the bottom rows of Table 5.

Table 5 Non-nested tests of rival models of financial indicators
(M1: spread; M2 lead; M3: stock ; M4: base money)

Test stat	M_1 vs M_2	M_2 vs M_1	M_1 vs M_3	M_3 vs M_1	M_1 vs M_4	M_4 vs M_1
N-test	-91.71^{**}	-225.83^{**}	-3.55^{**}	-32.85^{**}	-4.38^{**}	-26.60^{**}
NT-test	-0.17	-3.60^{**}	-0.26	-3.47^{**}	-0.56	-3.48^{**}
W-test	-0.17	-3.50^{**}	-0.26	-3.38^{**}	-0.56	-3.38^{**}
J-test	1.86	2.52^{**}	0.99	2.38^{**}	1.60	2.62^{**}
JA-test	-1.88	-2.52^{**}	0.99	$2.\ 38^{**}$	0.16	-2.62^{**}
$\varepsilon F(1,86)$	3.53	6.36^{*}	0.98	5.69^{*}	2.55	6.87^{*}
M_1	$AdjR^2$=05	L=-194.9	$AdjR^2$=.05	L=194.9	R^2=0.05	L=-194.87
M_2	$AdjR^2$=.02	L=-197.3	$AdjR^2$=.003	L=197.0	R^2=0.009	L=196.99
AIC	1.39	Fav M_1	2..34	Fav M_1	2.13	Fav M_1
SBC	1.39	Fav M_2	2.34	Fav M_2	2.13	Fav M_1

The above result, that the yield curve is good predictor of real economic activity compared to other financial indicators in Australia, accords with similar findings in the USA and other OECD countries as reported in the studies cited in Section 1 of the paper.

4. Recession predictions using the probit method

The use of real GDP growth as the dependent variable in the yield curve obfuscates predictions of recessions by mixing information on the timing of recessions with the degree of strength of the recession. A more accurate measure of the occurrence or otherwise of a recession could be quantified using a binary response or dummy variable. Such a variable could defined by (R_t=1) referring to the occurrence of a recession and (R_t=0) to its non-occurrence. The use of such a binary response or dummy variable to predict recessions using a probit methodology has been demonstrated in a recent study for the USA (Estrella and Mishkin, 1998).

The forecast of a binary response or recession dummy over a forecast horizon of j-quarters into the future based on the current spread term could be specified by a linear regression as follows:

$$R_{t+j} = \beta_0 + \beta_1 s_t + \varepsilon_t \qquad (1) \qquad \text{where the errors are i.i.d normal.}$$

The OLS estimation of equation (1) with a recession dummy will produce heteroscedastic errors, with negative variances, nonlinear probabilities, giving nonsense regressions (Greene, 1997: 874). Therefore, the above equation can be estimated only in probit framework thus:

$$\Pr(R_{t+j} = 1) = F(\beta_0 + \beta_1 s_t + \varepsilon_t) \qquad (2) \qquad \text{where } t= 1,2, \ldots.T .$$

The function F(.) is defined by a cumulative normal distribution for the standard normal variate s_t.

The log-likelihood function (L) for the above probit model would be:

$$L = \sum_i^n R_i \log[F(\beta_0 + \beta_1 s_{t-j} + \varepsilon_t)] + \sum_i^n (1 - R_i)\log[1 - F(\beta_0 + \beta_1 s_{t-j} + \varepsilon_t)] \qquad (3)$$

The parameters ($\beta_0\beta_1$) of the above function (3) could be estimated meaningfully by the method of maximum likelihood estimation (MLE) by applying the Newton-Raphson numerical iterative algorithm.

The goodness-of-fit of the probit model could be evaluated by the pseudo-R^2 criterion (Judge et al., 1985;776-8; Estrella and Mishkin, 1998). This criterion is computed as the ratio of the value of the maximum likelihood estimate (MLE) of the unrestricted log likelihood function (L_u) to the value restricted of the log-likelihood function of only the constant term (L_c) thus:

$$\text{pseudo-}R^2 = 1 - (L_u / L_c)^{-Lc/2} \qquad (4)$$

The goodness-of-fit of recessions over a j-quarters horizon based on the spread (s_t) defined as the difference between the long-term and short-term rates (10 year bond rate and the 90day bank bill rate) as estimated by the pseudo-R^2 are reported in Table 6:

Table 6 Probits on recession prediction j-quarters ahead via spread & Pseudo-R^2 goodness of fit measure. (1975Q3- 1997Q3)

F-horizon j	1	2	3	4	5	6	8	12
K (constant)	-1.10	-1.14	-1.19	-1.27	-1.24	-1.17	-1.10	-1.76
|t-stat|	(6.38)**	(6.33)**	(6.28)**	(6.19)**	(6.48)**	(6.45)**	(6.44)**	(5.84)**
s_j	-0.16	-0.22	-0.26	-0.31	-0.23	-0.17	-0.09	0.03
|t-stat|	(2.00)**	(2.62)**	(2.94)**	(3.37)**	(2.95)**	(2.40)**	(1.35)	(0.24)
Pseudo-R^2	0.05	0.10	0.13	0.18	0.14	0.08	0.02	0.01

Based on the statistical criteria of the highest pseudo-R^2 and statistically significant spread term, the best fitting probit equation for predicting a recession is the one for a 4-quarters horizon into the future (Table 6) as given by the following probit equation:

$$P(R_{t+4} = 1) = F(-1.27 - 0.31 s_t) \qquad (5)$$

The above best fitting probit function (5) quantifies in percentage terms the probability of the occurrence of a recession for different magnitudes of the spread term or inversions of the slope of the yield curve. The relation between yield curve inversions and the probability of recessions based on the above best fit probit equation (5) are reported in Table 7 below:

Table 7 Probability of recession predicted by the best probit model

$Pr(R_{t+4})$ %	5	10	20	30	40	50	60	70	80	90
Spread=s_t	1.32	0.12	-1.26	-2.28	-3.14	-3.98	-4.29	-5.65	-6.57	-8.10

The above results indicate that on the basis of the spread observed for 1997Q3 of nearly 1.45%, the probability of a recession would be less than 5% or most unlikely over the forecast horizon of 4-quarters ahead or during 1998Q3. Furthermore, an inversion of the slope of the yield curve or a spread of –3.98 will be required to predict a recession with 50% probability. The spread will have to exceed –8.10 to predict a recession with a probability of more than 90%. The recession probabilities from the best fitting probit model for a forecast horizon of 4-quarters are shown in Fig. 3. The highest probability of 60% of predicting a recession was reached in the 1990s. It should be noted that although the slope of the yield curve outperforms other financial indicators as a recession predictor it neither predicts with absolute certainty the onset or duration of recessions.

A deficiency of limited dependent variable probit models of time-series is its neglect of the dynamic structure of the dependent variable. This could be remedied by adding lagged dependent variables thereby increasing the plausibility of the assumption of zero mean, conditional on availability of information over time (t+j) (Dueker, 1997). Such an addition of a dynamic structure through the incorporation of a lagged dependent variable is similar to the addition of lagged dependent variables to improve the forecasting prowess of the linear regression model by making residuals free of serial correlation or white noise. The resultant probit model with a dynamic lag structure to capture the data generation process underpinning better could be defined as follows:

$$Pr(R_{t+j}=1) = F(\beta_0 + \beta_1 s_t + \beta_2 R_{t-1} + \varepsilon_t) \qquad (6)$$

The estimated dynamic probit equation for the yield curve is:

$$P(R_t=1) = F(-1.77 - 0.25 s_t + 1.94 R_{t-1}) \qquad (7)$$

The maximum likelihood estimates of the dynamic probit model are reported in Table 8 below:

Table 8 Probit recession predictions j-quarters ahead via spreads & Pseudo-R^2 measure of goodness of fit
(1975Q3-1997Q3)

Qtr j	1	2	3	4	5	6	8	12
k (constant)	-1.83	-1.76	-1.70	-1.77	-1.74	-1.62	-1.62	-1.63
|t-stat|	(5.88)**	(6.16)**	(6.41)**	(6.14)**	(6.40)**	(6.75)**	(6.79)**	(6.69)**
S_j	-0.24	-0.23	-0.19	-0.25	-0.17	-0.06	-0.02	0.03
|t-stat|	(2.08)*	(2.02)*	(1.89)**	(2.29)**	(2.03)	(0.66)	(0.26)	(0.32)
R_{t-1}	2.27	2.08	1.96	1.94	1.93	2.00	2.10	2.14
|t-stat|	(4.75)**	(4.57)**	(4.35)**	(4.42)**	(4.24)**	(4.32)**	(4.73)**	(4.86)**
Pseudo-R^2	0.43	0.42	0.41	0.44	0.41	0.36	0.36	0.36

The 4-quarter ahead forecast probabilities based on the best fit dynamic probit model are better than those obtained through the comparable non-dynamic probit model. The goodness of fit for the dynamic probit gives a pseudo-R^2 =0.44 compared to a pseudo-R^2 =0.18 for the non-dynamic probit model.

The predicted probability of recessions on the basis of different nominal spreads for the dynamic probit model of the yield curve are reported in Table 9.

Table 9. Probability of recession prediction based on the best fit dynamic probit model

$Pr(R_{t+4})$%	5	10	20	30	40	50	60	70	80	90
Spread=s_t	1.42	-0.06	-1.76	-3.05	-4.12	-5.16	-6.16	-7.13	-9.49	-10.28

On the basis of the observed spread of 1.45% for 1997Q3 the probability of occurrence of a recession is less than 5% 4-quarters ahead or in 1998Q3. A larger spread or slope inversion is required for predicting recessions with probability of 50% than for the probit model with the dynamic lag-structure. A noteworthy difference is that the predicted probabilities of a recession with the dynamic model appears to capture past recessions with a greater degree of fit (See Fig. 4). The inclusion of the lagged dependent variable has improved the fit the probit model as evidenced by the higher values of pseudo-R^2 (Table 7). The dynamic model appears predict better both the occurrence, severity and the duration of recessions than the non-dynamic version of the probit model. The inclusion of the past history of the probit prediction equation appears to improve the forecasting power of the probit model. The addition of the lagged dependent variable has buttressed the importance of the yield curve as a recession predictor.

5. Concluding observations

The slope of the yield curve outperforms other financial indicators as a predictor of real economic activity in Australia over forecast horizons of about 4 quarters or one year. The six episodes of economic downturn in Australia during the study period clearly show that the inversion of the slope of the yield curve precedes the onset of a recession. This observed lagged synchronisation of the slope of the yield curve with the turning points of the business cycle supports the hypothesis that the yield curve could predict in advance the changes in real GDP. The regression empirics revealed that the best fitting yield curve on the basis for the sample data was a yield curve that could predict real activity over a 4-quarter time horizon into the future. Furthermore, the yield curve as a predictor of recessions outperformed the predictions by rival financial indicators based on the stock market (M_2), money base (M_3) and the leading indicator (M_4).

The probit modelling of recessions revealed that inverted slope of the yield curve provided reliable predictions of recessions 4-quarters in advance. The probability of predictions and the fit of the probit equations improved dramatically when the probit model was enhanced by a dynamic lag structure.

The yield curve for Australia emerges as a simple forecasting tool giving a clear signal as to the onset of recessions about one year or 4-quarters in advance. The parsimony and simplicity of the yield curve which can be implemented using readily available data makes it a handy tool for supplementing forecasts from more complex macroeconometric models and for cross-checking judgmental forecasts.

Fig.1

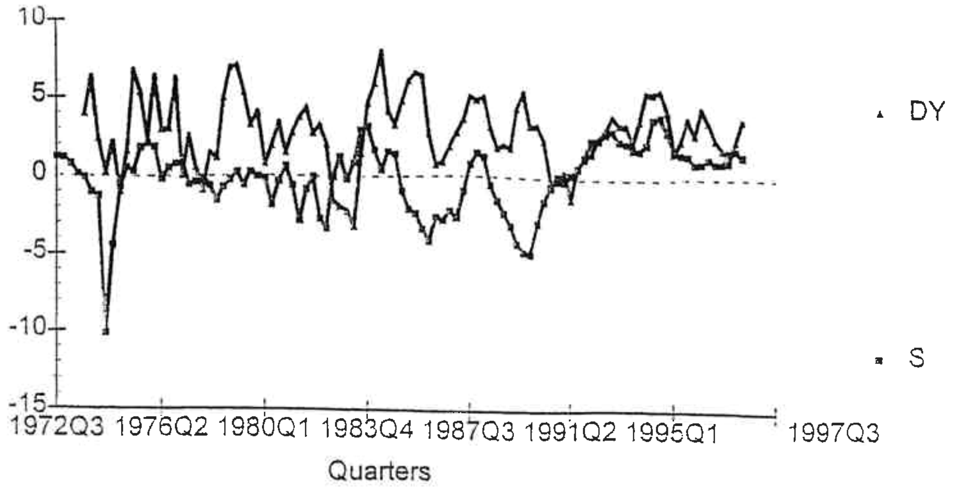


Fig.2

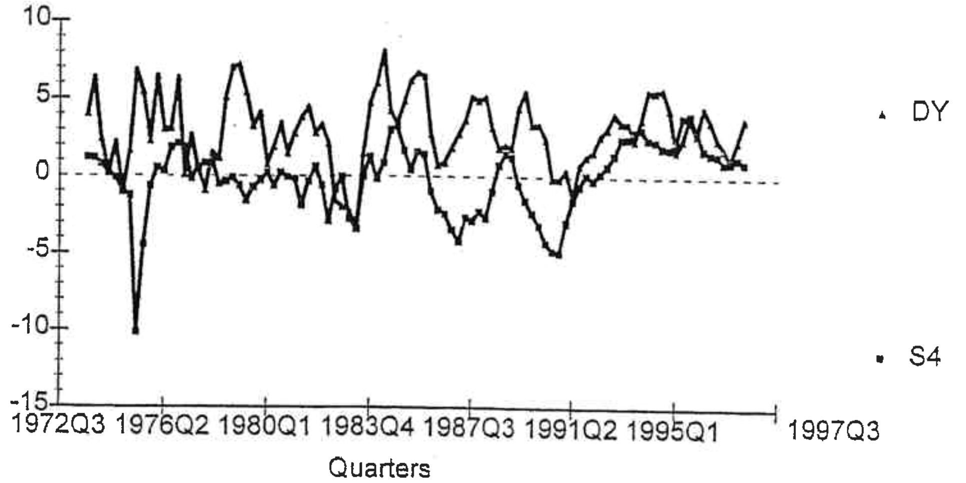


Fig.3

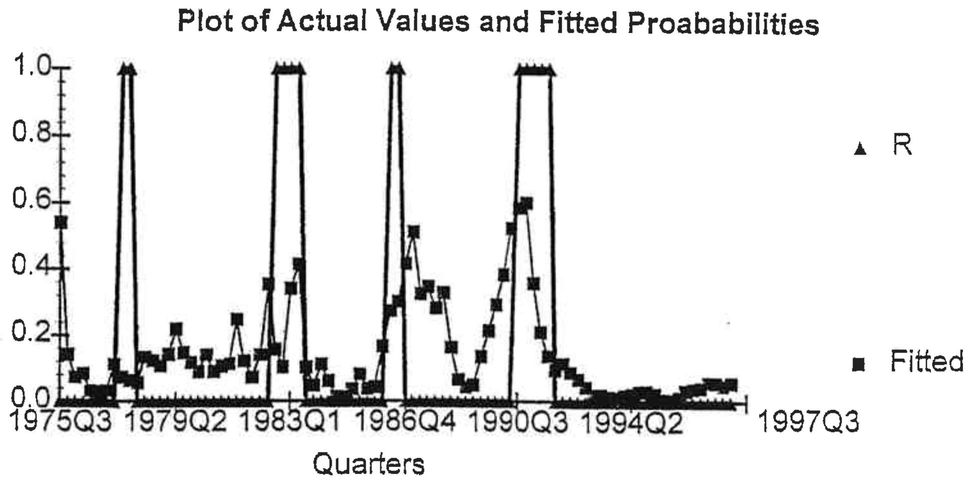
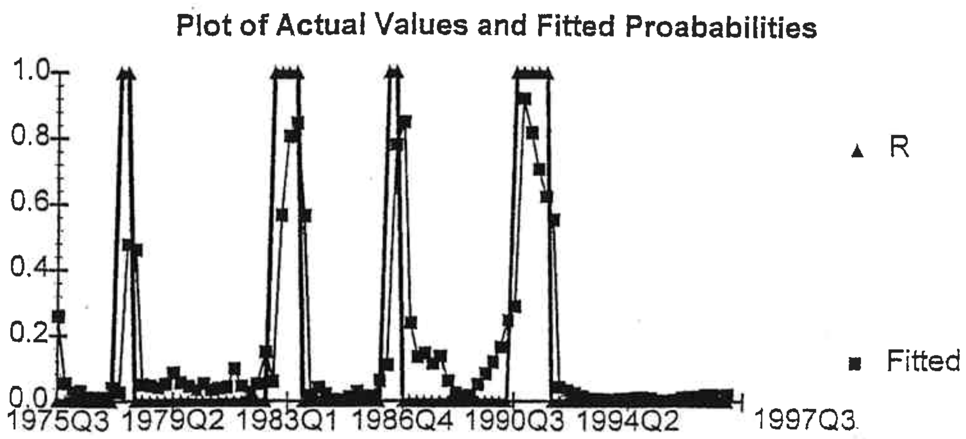


Fig.4



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